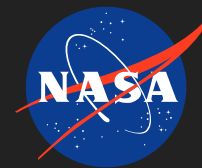


High energy density additives for Hybrid Fuel Rockets to Improve Performance and Enhance Safety

Completed Technology Project (2011 - 2012)



Project Introduction

We propose a conceptual study of prototype strained hydrocarbon molecules as high energy density additives for hybrid rocket fuels to boost the performance of these rockets without compromising safety and reliability. Use of these additives could extend the range of applications for which hybrid rockets become an attractive alternative to conventional solid or liquid fuel rockets. The objectives of the study were to confirm and quantify the high enthalpy of these strained molecules and to assess improvement in rocket performance that would be expected if these additives were blended with conventional fuels. We confirmed the chemical properties (including enthalpy) of these additives. However, the predicted improvement in rocket performance was too small to make this a useful strategy for boosting hybrid rocket performance.

Hybrid rockets use a solid fuel with a liquid or gaseous oxidizer. They have advantages over solid fuel rockets for certain space applications because the solid fuel component is more stable than combined solid fuel and oxidizer, and advantages over liquid fuel rockets because the fuel does not require cryogenic storage or pumping and the burn rate can be controlled by regulating the flow of oxidizer. Ideal fuels should have a fast regression rate, high density and good mechanical stability (so it will not break apart during burning). A current project at ARC is evaluating hybrid rockets comprised of solid paraffin fuel and cryogenic nitrous oxide and LOX oxidizer and has shown that higher regression rates are needed. Strained cyclic hydrocarbons have positive enthalpy and can be blended with paraffins to make fuels for hybrid rockets, but to be effective the resulting solid must have physical and mechanical characteristics at least comparable to the pure paraffin fuels. The stable hydrocarbon molecules with the highest strain energy are comprised of triangular rings of carbon atoms (cyclopropane), but these are gases at normal temperatures and pressures. Recently, chemists have synthesized molecules (called ivyanes, shown in Figure 1) containing multiple cyclopropane rings bonded together. We propose investigating blends of ivyanes and paraffins to determine their thermochemical and physical properties. We will first carry out simulations to predict enthalpy, density and stability of these blends using first principles chemistry and physics methods. Previously, first principles calculations by two of us (Jaffe and Zehe, J. Organic Chem. 2010, 75, 4387) demonstrated thermochemical properties can be determined to an accuracy of 2 kJ/mol for hydrocarbon molecules containing 10-20 carbon atoms. In the second phase, the density, melting temperature and heat of sublimation of solid ivyanes and the blends will be determined from molecular dynamics simulations.

Anticipated Benefits

Any NASA funded mission that is using hybrid fuel rocket technology can benefit from this technology.



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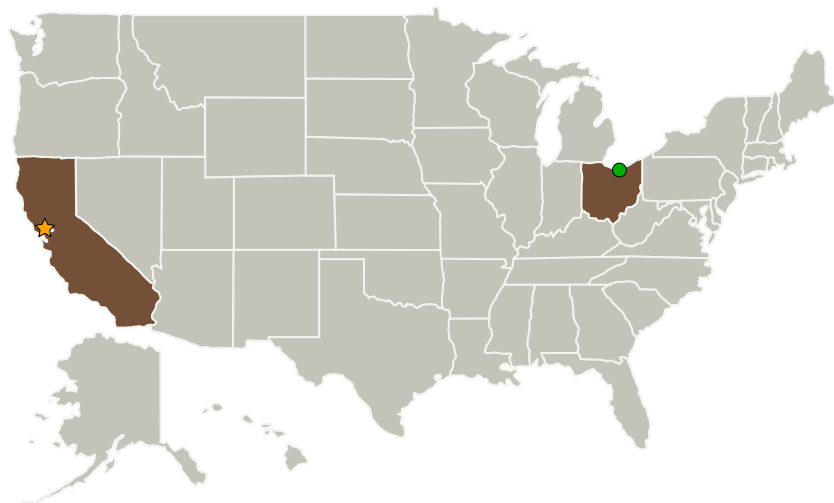
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Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
ERC Inc.	Supporting Organization	Industry	
● Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio

Primary U.S. Work Locations

California	Ohio
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Links

AIAA2013-3968: Characterization and Evaluation of High Energy Hydrocarbon Additives for Paraffin-Fuel Hybrid Rockets
(<http://www.aiaa.org>)

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

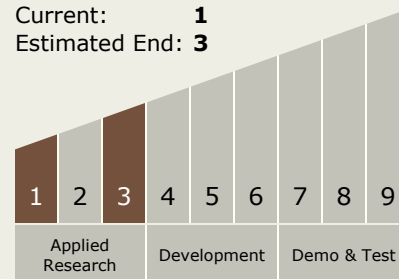
Harry Partridge

Principal Investigator:

Richard L Jaffe

Technology Maturity (TRL)

Start: **1**
Current: **1**
Estimated End: **3**



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Technology Areas

Primary:

- TX01 Propulsion Systems
 - └ TX01.1 Chemical Space Propulsion
 - └ TX01.1.5 Hybrids